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ABSTRACT

One hundred and twenty-four high school students were randomly assigned to four groups: 33 subjects memorized the rule statement before, 29 subjects memorized the rule statement during, and 30 subjects memorized the rule statement after instruction in rule application skills. Thirty-two subjects were not required to memorize rule statements. Neither memorization nor temporal placement of the memorization tasks significantly affected performances on posttest or rule application retention test. Memorization of rule statements after mastering rule-governed behavior increased the relationships between several performance measures and reasoning ability test scores. Memorization of rule statements prior to rule application instruction facilitated acquisition of rule-governed behavior and reduced variability in students' performance during acquisition of rule application skills. (Author)

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EFFECTS OF MEMORIZATION OF RULE STATEMENTS ON ACQUISITION AND RETENTION OF RULE-GOVERNED BEHAVIOR IN A COMPUTER-BASED LEARNING TASK[1]

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by

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EFFECTS OF MEMORIZATION OF RULE STATEMENTS ON ACQUISITION AND RETENTION OF RULE-GOVERNED BEHAVIOR

Though intellectual skills such as rule application skills are more resistant to forgetting as compared with lower order intellectual skills and verbal information (Lahey, 1941; Gagne and Bassler, 1963) the lack of performance on retention tests in school-learned subjects has been noted (Layton, 1932; Lahey, 1941; Pressey, Robinson, and Harrocks, 1959). Because rules are highly resistant to forgetting, the inability to correctly apply a rule in a retention task can be attributed to lack of retrieval of the correct rule rather than not having stored the rule in memory (Bruner, 1961).

Several educational psychologists in designing instructional programs for rule learning have included a requirement for the student to learn the rule statement. Gagne (1970) would require the student to make a verbal statement of the rule after having mastered the appropriate rule application skills. Evans, Homme, and Glaser (1962) would require the student to correctly complete an incomplete rule statement within the rule application instructional program. Merrill (1972) would also require the student to learn the rule statement within the application skills instruction. Being able to repeat the rule statement from memory would allow the student to talk about the rule on a later occasion (Gagne, 1970) and may serve as a valuable cue for subsequent application of the rule (Merrill, 1972).

The findings of two research studies investigating the role of verbalizing rules during acquisition of rule application skills are inconclusive. Gagne and Smith (1962) reported that Ss who were instructed to say aloud their reasons for making each step in the solution to a practice problem

reached a correct solution for the final task in fewer attempts than did Ss who were not required to verbalize. This difference increased as the problems became more difficult. In addition, those Ss who were required to verbalize their reasons for each problem solution step were able to formulate general principles of problem solution after correctly solving the final task problem bettter than those Ss not required to verbalize during the practice attempts. Results of the Seidel-Rotberg (1966) study showed that the students who were required to give back the rules in the words of the instructor (in this case, the instructional program) during the course of learning computer programming also were able to do this quite well on a criterion test. Further results indicated that these subjects did not do as well in writing computer programs on the criterion test as subjects who had simply to write the names of the rules during the training or subjects who learned without either additional requirement. A retention test involving the application of concepts learned during the instructional program in writing computer programs showed no statistically significant difference among the three groups.

The purpose of the present study was to investigate the effects of memorization of rule statements on acquisition and retention of rule-governed behavior in a computer-based, criterion referenced instructional task.

Method

Subjects

The subjects were 124 students in the Florida State University Developmental Research School selected randomly from grades 9-12.

Instruments

A series of studies by P. F. Merrill and his students (Merrill, 1970; Merrill, et al., 1972; 1973) have produced results showing Aptitude

Treatment Interactions (ATI's) in a rule-learning task similar to that used in this study. Following the results of the P. F. Merrill studies, the Letter Sets Test from the Kit of Reference Tests for Cognitive Factors (French, Ekstrom, and Price, 1963) was selected as a measure of inductive reasoning. The Ship Destination Test from the same source was selected to measure general reasoning.

The learning task used in this study was an adaptation of materials based on the APL programming language used in several previous studies (Merrill, et al., 1972; 1973). The learning task consisted of five modules, each based on one APL rule. Each module consisted, depending upon the group assignment, of a rule statement, examples of correct application of the rule, problems to which the rule must be applied to compute the correct answer, and a requirement to memorize the rule statement. The results of previous research show the first three rules relatively easy and the fourth and fifth rules substantially more difficult for Ss to learn.

The instructional program was written in the Coursewirter II language and presented to the subjects by the IBM 1500/1800 computer-assisted instructional system at the FSU CAI Center. The learning materials and all tests in the APL-based instructional program were presented on the 1510 cathode ray tube (CRT).

Procedure

The study was administered in three sessions including an ability testing session, the instructional task and posttest session, and the retention test session. The ability tests were administered to all subjects in one large group session and in one smaller group session, necessitated by the confines of the University School schedule. Immediately preceding the administration of the tests, a short explanation of the general purpose and

schedule of the study was given to the subjects. The ability testing session (paper and pencil) lasted for about one hour.

The instructional task session was presented by the CAI system in the FSU CAI Center. The subjects were randomly assigned to four groups. The four groups were a No Memorization of rule statement group (N=32), a Rule Statement Memorization Prior to instruction group (N=33), a Rule Statement Memorization During instruction group (N=29), and a Rule Statement Memorization After instruction group (N=30). Before receiving instruction in learning the APL rules, all Ss were presented with warm-up materials designed to familiarize each S with the operation of the terminal and to indicate in advance of the presentation of the experimental materials what was expected of him during the instructional program.

Each of the five modules of the rule application instructional program presented to all groups consisted of three levels of instruction in rule application skills. The student was required to meet the minimum criterion performance of two-thirds of the rule application problems correct on each level before moving to the next level. The supporting stimuli of the rule statement and accompanying examples were faded from one level to the next until the criterion performance consisted of the presentation of a problem for which S was required to compute the correct answer without the aid of supporting stimuli. If the student did not meet the minimum performance requirement of two problems correct out of the three that were presented at any one level, he received up to four additional displays of that level. When criterion was reached at each of the three levels of rule application instruction, Ss then received the instructional module for the next task which depended upon the group to which S was assigned. The modules were presented randomly until all five rules were learned.

This basic sequence of instructional tasks was presented to all Ss with the following exceptions. The Rule Statement Memorization Prior group was required to memorize the rule statement prior to receiving instruction in application of the rule. The Rule Statement Memorization During group was required to memorize the rule statement after reaching the criterion of two-thirds correct of the problems presented in the first level of rule application instruction. The Rule Statement Memorization After group was required to memorize the rule statement after meeting criterion on all levels of application problems associated with the rule. The No Memorization group was not required to memorize the statement of the rule.

The rule statement memorization instruction consisted of several levels of requirements on the part of the Ss to complete a rule statement by typing the appropriate words using the terminal keyboard. The supporting stimuli of partial rule statements and examples were faded until the criterion performance consisted of the presentation of a partial example for which S was required to type the statement of the correct rule to be applied. A posttest consisting of three problems for each APL rule was administered to each S immediately after completion of the instructional task.

Two weeks after the instructional session the subjects returned to the CAI Center to receive administration of the rule application retention test and the rule statement retention test.

Dependent Measures

In addition to scores on the two cognitive ability tests, posttest, and retention test, data were obtained for each S during the rule application instruction program on the following criteria: display latency, sample

test item response latency, and number of sample test items attempted before meeting the minimum performance criterion required by the program. Display latency was the measure of the time between the initial display of study material and the start of the display of the first problem of that level of instruction. Sample test item response latency was the time between the initial display of a test item and the answering of that test item imbedded within the rule application instruction.

Data were also collected on the total amount of time required for each S to complete the instructional program including the rule statement memorization instructional materials. This total instructional time did not include the time required for testing activities.

Results and Discussion

A summary of mean percentage correct on the ability tests and on the task performance tests is presented in Table 1. All groups performed similarly on each test with the exception of the rule statement retention test where, as would be expected, the group that was not required to memorize rule statements performed less well than the rule statement memorization groups. All groups performed at a higher level on the rule application posttest than was required within the instructional program--81-88% on the posttest as compared to 67% required in the instructional program. Performance of rule-governed behavior on the rule application retention test was somewhat lower than that on the posttest but substantially higher than that on the rule statement retention test. This result is consistent with results of previous research indicating that intellectual skills such as rule-governed behavior are more resistant to forgetting than memorized verbal information (Lahey, 1941; Layton, 1932; Gagne and Bassler, 1963).

Analysis of variance F ratios for the instructional task test scores are also reported in Table 1.

Insert Table 1 about here

Since the experimental procedure required all Ss to perform at a minimum criterion level on each rule module before proceeding to the next, no significant treatment differences were expected in mean posttest scores. The results from ANOVA suggest that the minor difference in treatment group posttest means was due to chance. Similarly, the differences in treatment group rule application retention test means were not statistically significant. However, linear regression analyses revealed significant ATI's using posttest scores and rule application retention test scores as criterion variables with Ship Destination Test as covariable. Figure 1 illustrates the relationship between the reasoning ability test scores and rule application retention test scores for each treatment group. The regression lines plotted with posttest scores as criterion had a similar relationship as those in Figure 1. The greater positive relationship between reasoning scores and performance test scores in the Rule Statement Memorization After group is somewhat surprising as the instructional program for learning rule-governed behavior was the same for the Rule Statement Memorization After group as for the No Memorization group. Yet, the relationship between reasoning ability and posttest performance was greater for Ss in the Rule Statement Memorization After group than for Ss in the No Memorization group. Apparently the requirement of memorizing a rule statement after having mastered the behavior required by the rule increases the relationship between reasoning ability and test performance as compared to not being

required to memorize the rule statement at all.

Insert Figure 1 about here

The rule statement retention test required each S to type the statement of the rule that would be used to compute the correct answer to each of five problems, each problem representing one of the previously learned APL rules. These statements were evaluated independently by two expert APL programmers. A correct rule statement was awarded 10 points with fewer points being given for partially correct answers. The product moment correlation between the total scores awarded each S by the two evaluators was .94 which indicated a high degree of scoring consistency between evaluators. For purposes of further analysis, the average of the two total scores for each S was used. As reported in Table 1, analysis of variance revealed a significant treatment effect. Subsequent t tests revealed no significant mean performance differences between the three rule statement memorization groups, or between the Rule Statement Memorization During group and the No Memorization group. However, mean scores indicated significantly lower scores for Ss in the No Memorization group than Ss in the Rule Statement Memorization Prior group ($t = 2.39$, $df = 120$, $p < .05$) and for Ss in the Rule Statement Memorization After group ($t = 2.79$, $df = 120$, $p < .05$).

Though Ss in the No Memorization group were not required to memorize rule statements at any time, their performance on the rule statement retention test did indicate that they could give minimally correct rule statements two weeks after rule application instruction. Surprisingly, the performance of Ss in the Rule Statement Memorization During group was not significantly different from that of Ss in the No Memorization group. All Ss who memorized

the rule statements during rule application instruction did, in fact, memorize the rule statements just as thoroughly as Ss in the other two rule statement memorization groups but at a different point in the total instructional program. The interruption of rule application instruction to fulfill the rule statement memorization requirement and then the subsequent return to the rule application instruction seems to have debilitated Ss' ability to restate the rule statement on the retention test.

The effect of memorization of rule statements on the acquisition of rule-governed behavior is shown by analysis of the following dependent measures.

The number of sample test items attempted during the rule application instruction is a gross measure of the subject's performance in the instructional program. The number of sample test items required to meet the minimum performance criterion is directly related to difficulty S had in mastering the instructional materials. The minimum number of sample test items that any S would have received was 45--three for each of three levels of the five rule modules. Of great interest are the standard deviations of the Rule Statement Memorization Prior group (See Table 2). The instructional program presented to Ss in this treatment group produced rule-governed behavior so uniformly good that the variability was reduced to the point where analysis of variance on this data might be considered to be inappropriate. The range of number of sample test items attempted by Ss in the Rule Statement Memorization Prior group was 45-57 with a mean of 46.6. The ranges of sample test items for the No Memorization group, the Rule Statement Memorization During group, and the Rule Statement Memorization After group were 45-141, 45-123, and 45-115 respectively. From this evidence it would seem safe to conclude that requiring memorization of rule statements

prior to rule application instruction is the best of the four instructional strategies to facilitate uniformly good rule-governed behavior with a minimum number of practice test items.

Insert Table 2 about here

Linear regression analysis was employed to probe for possible ATI effects on the number of rule application sample test items attempted. Figure 2 illustrates the significant interaction between Treatment and Ship Destination Test scores using number of sample test items as criterion where number of sample test items has a high negative relationship to general reasoning ability for Ss in the Rule Statement Memorization After group. This relationship is also present for Ss in the other groups but to a lesser degree. In fact, this relationship was substantially reduced for Ss in both the No Memorization group and the Rule Statement Memorization Prior group. The similarity in slopes of the regression lines for the latter two groups should be interpreted in light of the substantial difference in treatment group means whereby the instructional program for the Rule Statement Memorization Prior group reduced the mean number of sample test items required to meet the minimum performance criterion required of all Ss in rule-governed behavior.

Insert Figure 2 about here

Another dependent measure used as an indication of Ss' performance in the instructional program is display latency. The amount of time that the

instructional materials are displayed is directly related to the difficulty S had in learning rule-governed behavior. As would be expected, mean display latency increased, from about 30 seconds for each of the three previously demonstrated easier rule modules to about three minutes for each of the two more difficulty rule modules (See Table 3). The instructional program which required Ss to memorize rule statements prior to receiving instruction in rule-governed behavior facilitated learning of rule application skills such that it produced uniformly low requirements for study time as compared to the instructional programs for the other treatment groups. When display latency for each of the five rule modules was totaled, the total display latency variance for the Rule Statement Memorization Prior group was significantly less than the variance for the No Memorization group ($F = 5.42$, $df = 31/32$, $p < .01$), the Rule Statement Memorization During group ($F = 2.27$, $df = 29/32$, $p < .05$), and the Rule Statement Memorization After group ($F = 2.84$, $df = 28/32$, $p < .01$). Though the measure of display latency is not as important as other measures reported in this paper, these results do give further evidence as to the effectiveness of the instructional program for the Rule Statement Memorization Prior group in facilitating the acquisition of rule-governed behavior.

Insert Table 3 about here

One additional measure used to indicate Ss' performance within the instructional programs is the amount of time S takes to respond to the sample test items. Although this measure was highly related to the number of sample test items attempted (product moment correlation of .72), it does give additional information of the effectiveness of the instructional

programs. Consistent with the results of the analyses of several other dependent measures, the instructional program for the Rule Statement Memorization Prior group significantly reduced variability in total test item response latency as compared with the programs for the No Memorization group ($F = 7.7$, $df = 31/32$, $p < .01$), the Rule Statement Memorization During group ($F = 5.03$, $df = 29/32$, $p < .01$), and the Rule Statement Memorization After group ($F = 6.42$, $df = 28/32$, $p < .01$). As depicted in Table 4 the mean sample test item response latency for Ss in the Rule Statement Memorization Prior group was consistently less than that for each of the other three groups on each rule module. Mean total sample test item response latency indicated less time necessary to respond to test items for Ss in the Rule Statement Memorization Prior group than for Ss in the No Memorization group ($t = 3.502$, $df = 63$, $p < .05$), and Ss in the Rule Statement Memorization During group ($t = 3.168$, $df = 61$, $p < .05$). Although not significant at the alpha level of .05, the difference between performance of Ss in the Rule Statement Memorization Prior group and Ss in the Rule Statement Memorization After group ($t = 1.67$, $df = 62$, p .10) was in the same direction with Ss memorizing rule statements prior to rule application instruction requiring less time to respond to the sample test items imbedded in the rule application instruction materials.

Insert Table 4 about here

The total time, excluding testing time, required by each S to complete the instructional program, including both the sections on rule application and on rule statement memorization, was recorded as a measure of the

overall efficiency of the total program. Mean times for the No Memorization group, the Rule Statement Memorization Prior group, the Rule Statement Memorization During group, and the Rule Statement Memorization After group were 21, 53, 60, and 50 minutes respectively. The rule statement memorization groups required substantially more time to complete the instructional program than did the group not required to memorize rule statements. As the three rule statement memorization groups not only mastered rule-governed behavior but also performed the additional task of memorizing the rule statements, this finding is not at all surprising.

Conclusions and Implications

The results from both the posttest and the rule application retention test clearly show that memorization of rule statements is not necessary for acquisition and retention of rule-governed behavior in a forced mastery learning situation. On the other hand, rule statement memorization was not detrimental to performance on the posttest as was the case in the Seidel-Rotberg study.

It is also clear that memorizing rule statements before rule application instruction occurs does facilitate acquisition of rule-governed behavior and reduces variability in the performance of students during this acquisition. As desirable as this effect is instructionally, it must be tempered with the fact that memorization takes a substantial amount of time. In this light, if instructional time is at a premium, students probably should not be required to memorize rule statements.

It is not possible from the results of this study to explain the unusual effect of increased relationships between performance on several dependent measures and reasoning ability test scores in Ss who memorized rule statements after meeting criterion in the rule application skills. This effect

should be investigated further to determine if it is caused by memorization of rule statements or if memorization of any statement unrelated to the application of the rule would have the same effect.

Implications of these findings for instructional practices could be summed up as follows. (1) If memorization of a rule statement is required in an instructional program designed to teach rule application skills, the memorization requirement should be fulfilled prior to instruction in rule application skills. (2) If the goals of an instructional program are associated with only rule-governed behavior in long-or short-term retention situations, memorization of rule statements is not necessary. (3) If total instructional time is limited and all instruction must take place during this time, memorization of rule statements should not be included in the instructional program. (4) If some goals of an instructional program are associated with facilitating performance during the acquisition of rule-governed behavior, memorization of rule statements should be required prior to instruction in rule application skills. (5) If one purpose of the instructional program is to reduce learning errors and accompanying frustration and/or anxiety, memorization of rule statements should be required prior to instruction on rule application skills.

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FOOTNOTES

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Table 1

Mean Percentage Correct on Ability Tests and Instructional Task Tests and Results of Analysis of Variance on Instructional Task Test Scores

Group	Ability Test		Instructional Task Test		
	Letter Sets	Ship Destination	Rule Application Posttest	Rule Application Retention Test	Rule Statement Retention Test
No Memorization	50	40	81	59	25
Rule Statement Memorization Prior	58	49	88	63	43
Rule Statement Memorization During	55	44	88	61	36
Rule Statement Memorization After	57	55	85	63	47
ANOVAR, df = 3/120, F_c = 2.68			F = 1.205	F < 1.00	F = 2.956

Table 2

Treatment Group and Rule Means and Standard Deviations

for Number of Rule Application Sample Test Items Attempted

Group		Rule					Overall Treatment
		1	2	3	4	5	
No Memorization	Mean	9.0	10.0	9.1	15.4	15.4	58.9
	SD	0	4.8	.5	10.2	10.8	21.8
Rule Statement Memorization Prior	Mean	9.0	9.2	9.0	9.4	10.2	46.6
	SD	0	.7	0	1.1	2.9	3.7
Rule Statement Memorization During	Mean	9.2	9.2	10.1	14.1	12.0	54.6
	SD	1.1	1.1	5.0	9.8	7.6	17.3
Rule Statement Memorization After	Mean	9.3	9.3	9.3	14.5	13.9	55.8
	SD	.9	.9	.9	11.6	11.6	21.2
Overall Rule	Mean	9.1	9.4	9.3	13.3	12.8	
	SD	.6	2.6	2.5	9.3	8.9	

Table 3

Treatment Group and Rule Means and Standard Deviations for

Rule Application Display Latency in Seconds

Group		Rule					Overall Treatment
		1	2	3	4	5	
No Memorization	Mean	29.8	30.9	27.0	190.4	263.0	531.0
	SD	18.9	26.3	19.0	171.6	229.9	375.4
Rule Statement Memorization Prior	Mean	20.5	19.7	14.8	79.9	101.8	237.0
	SD	17.9	8.3	8.9	82.8	84.2	161.2
Rule Statement Memorization During	Mean	37.1	39.7	28.9	242.5	182.8	531.0
	SD	17.8	27.5	27.0	156.4	129.1	242.9
Rule Statement Memorization After	Mean	31.1	27.2	27.0	156.4	203.8	445.5
	SD	19.1	14.5	20.9	133.6	196.1	271.6
Overall Rule	Mean	29.4	29.2	24.2	163.1	186.9	
	SD	19.2	21.7	19.6	149.3	177.1	

Table 4

Treatment Group and Rule Means and Standard Deviations for

Rule Application Sample Test Item Response Latency in Seconds

Group		Rule					Overall Treatment
		1	2	3	4	5	
No Memorization	Mean	52.5	72.9	57.8	250.0	304.9	738.2
	SD	23.9	54.8	18.8	285.6	270.8	491.2
Rule Statement Memorization Prior	Mean	46.3	62.3	53.2	116.2	141.3	419.3
	SD	12.4	16.3	18.0	72.1	114.9	117.3
Rule Statement Memorization During	Mean	61.7	74.1	68.2	256.8	200.5	661.3
	SD	27.6	20.6	64.5	249.1	178.5	397.7
Rule Statement	Mean	53.5	69.4	55.3	180.5	201.6	560.3
	SD	26.4	30.1	25.3	155.7	331.3	449.2
Overall Rule	Mean	53.3	69.6	58.5	199.8	211.9	
	SD	23.5	34.0	36.5	213.2	240.9	

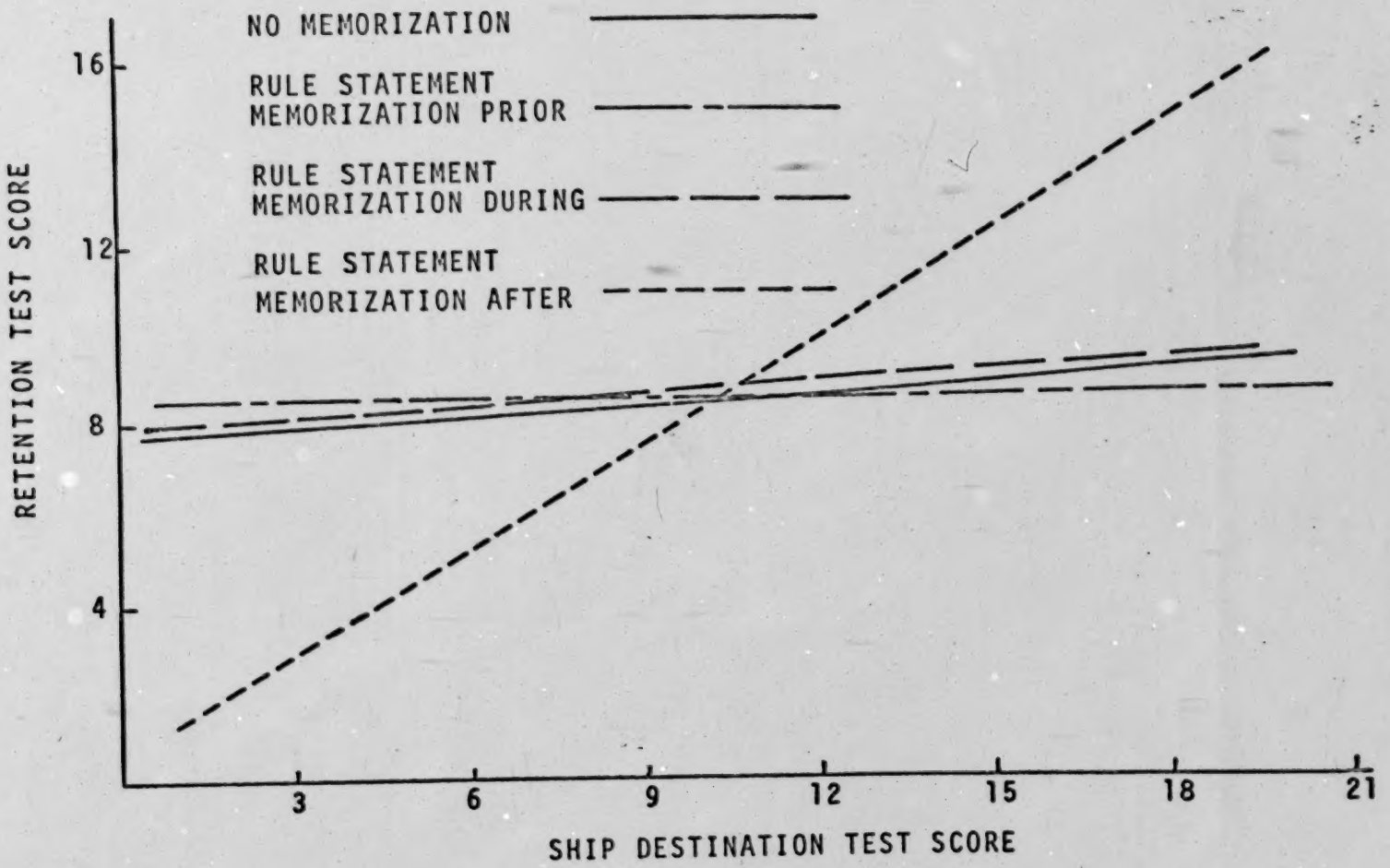

Figure 1. Interaction of Ship Destination Test Scores and Treatments with Retention Test Scores as Criterion.

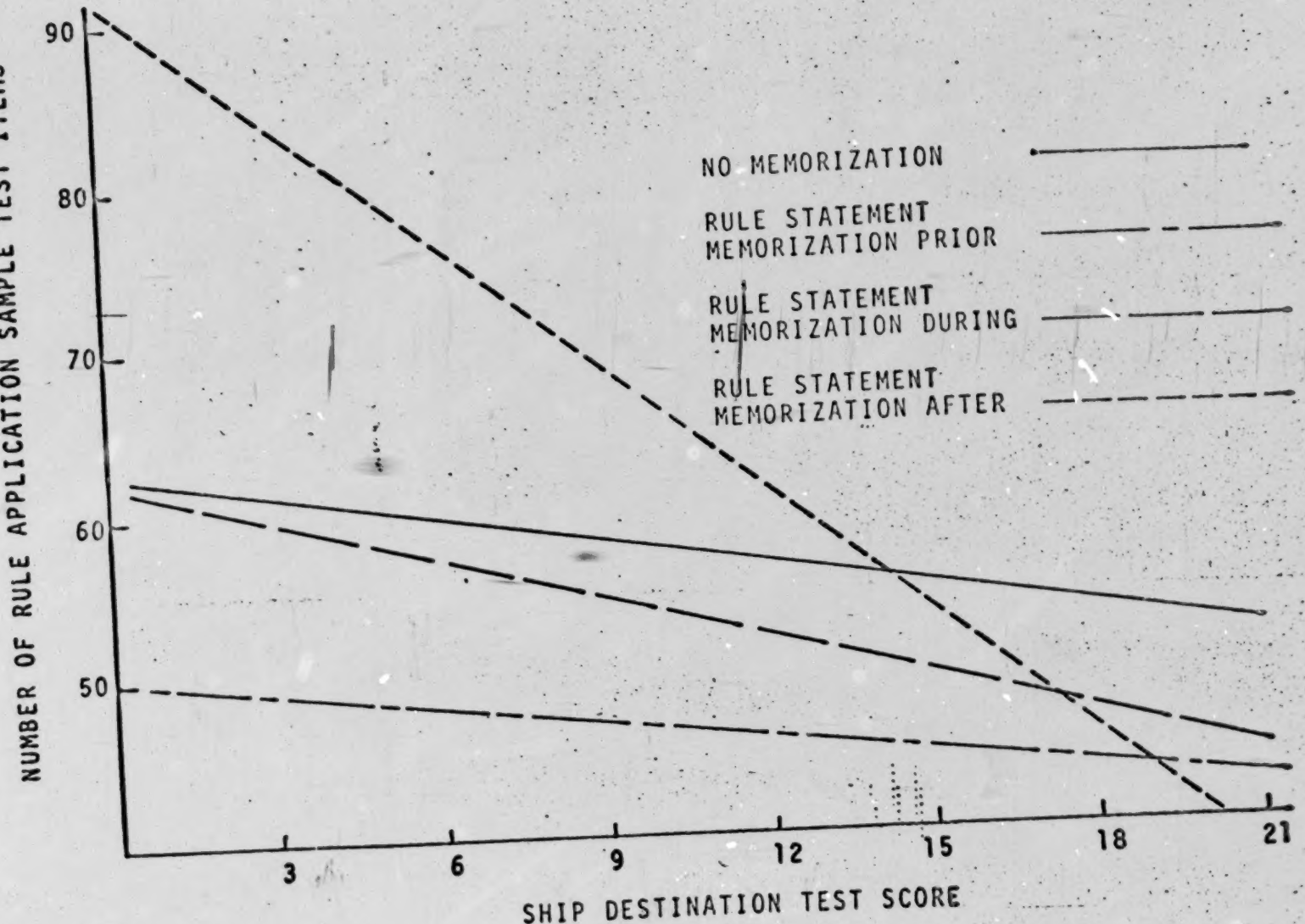

Figure 2. Interaction of Ship Destination Test Scores and Treatments with Number of Rule Application Sample Test Items as Criterion.

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